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## Abstract

**Background**

Health-adjusted life expectancy is a summary measure of population health that combines mortality and morbidity data into a single index. This article profiles differences in health-adjusted life expectancy across income categories for a representative sample of the Canadian population.

**Data and methods**

Mortality data were obtained from the 1991-2001 Canadian census mortality follow-up study, which linked a 15% sample of the 1991 adult non-institutional population with 11 years of death records from the Canadian Mortality Data Base. Information on morbidity was obtained from the Health Utilities Index Mark 3 instrument on the 2000/2001 Canadian Community Health Survey. The Sullivan method was used to compute health-adjusted life expectancy for national deciles of population ranked by income.

**Main results**

For both sexes, and with few exceptions, a nearly linear gradient across income deciles emerged for health-adjusted life expectancy at age 25. Compared with people in higher-income deciles, those in lower-income deciles had fewer years of health-adjusted life expectancy. These disparities were substantially larger than those revealed by life expectancy alone.

**Interpretation**

These findings highlight the generally worse health-related quality of life of lower-income groups. The results demonstrate that assessments of socio-economic disparities in health should include the effects of both mortality and morbidity.

## Keywords

health inequalities, Health Utilities Index, life expectancy, socio-economic, Sullivan method

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The dramatic increase in life expectancy in Canada and other economically developed nations during the last century stands as testimony to the success of improvements in public health and advances in medical care.[1] But despite these gains in longevity, inequalities in health outcomes across different subpopulations are still pervasive in Canada and other industrialized countries.[2-6]

Irrespective of how socio-economic status is defined and measured (by income, educational attainment or occupational prestige), mortality rates show a gradual but systematic increase at successively lower levels of the socio-economic hierarchy. Nonetheless, time-series analyses for Canada suggest that, in absolute terms, socio-economic differences in mortality have been diminishing over recent decades, with the specific patterns dependent on sex and the cause of death considered.[7,8]

Mortality, however, is only one aspect of population health. It is now widely recognized that information on morbidity (including disability and reduced health-related quality of life) is crucial for monitoring health trends, setting priorities, and conducting cost-effectiveness analysis of population-level interventions. Because morbidity varies by socio-economic status,[2,3,9-12] a complete assessment of health disparities requires summary measures reflecting the effects of differences in both mortality and morbidity across socio-economic categories.[13-15] Accordingly, a variety of summary measures, which integrate information on mortality and morbidity into a single numeric index, have been developed.[16-18]

A number of studies in Canada have calculated summary measures in order to examine broad national patterns of mortality and morbidity,[19] regional variations in population health,[20] the population health impact of specific diseases and risk factors,[21-25] and whether population health has been improving over time.[7,26,27] Few investigations in the Canadian context have focused on socio-economic differences in summary measures of population health, and those that have done so have relied primarily on macro-level indicators (such as neighbourhood income) rather than micro-level indicators (such as household income),[28-30] thereby almost

certainly attenuating the association between socio-economic status and health. One Canadian study used micro-level indicators for analyses of socio-economic disparities in health, but only within a single province.[31]

This article examines socio-economic differences in health for a nationally representative sample of the adult population of Canada, using a summary measure known as *health-adjusted life expectancy*.[32] By weighting years of life according to their quality, health-adjusted life expectancy converts the conventional, purely mortality-driven life expectancy measure into expected equivalent years of full health. This study combines mortality data from the 1991-2001 Canadian census mortality follow-up study[33] with information about health-related quality of life from the 2000/2001 Canadian Community Health Survey to estimate health-adjusted life expectancy for different income groups.

## Data and methods

### Data source

#### *The 1991-2001 Canadian census mortality follow-up study*

Death data were obtained from the 1991-2001 Canadian census mortality follow-up study, conducted by Statistics Canada in collaboration with the Canadian Population Health Initiative. With probabilistic linkage techniques, a 15% sample ($n$ = 2,735,152) of the non-institutional population aged 25 or older who completed the 1991 census long-form questionnaire (the cohort) was matched to 11 years of death records (June 4, 1991 to December 31, 2001) from the Canadian Mortality Data Base. The linked file contains information on various demographic characteristics, socio-economic status, activity limitations, disability, and cause and date of death. Additional methodological details on the construction and contents of the linked file have previously been reported.[33]

#### *The Canadian Community Health Survey*

Data on health-related quality of life were derived from the 2000/2001 Canadian Community Health Survey (cycle 1.1). The Canadian Community Health Survey is an ongoing cross-sectional survey that collects information on health status, health determinants, and health care utilization. It is representative of the household population aged 12 or older in all provinces and territories, excluding residents of institutions, of Indian Reserves and Crown Lands, of Canadian Forces bases (military and civilian residents) and of certain remote regions, and full-time members of the Canadian Forces. The response rate for cycle 1.1 was 84.7%. For consistency with the Canadian census mortality follow-up study, the present investigation was restricted to respondents aged 25 or older ($n$ = 106,283). More detailed descriptions of the Canadian Community Health Survey design, sample, and interview procedures can be found in other published reports and on the Statistics Canada website.[34,35]

### Definitions

#### *Income deciles*

For the census mortality linked file, deciles (tenths) of population ranked by income adequacy were created. First, for each economic family or unattached individual in the non-institutional census population of all ages, total pre-tax, post-transfer income from all sources was pooled across all economic family members and divided by the weighted family size (or "equivalent person unit" scale). An economic family is a grouping of two or more individuals living in the same household or dwelling unit who are related by blood, marriage or adoption.[36] Unattached individuals are economic families of size 1. Under the weighting system, the first person received a weight of 1.0, the second person, 0.4, and all subsequent persons, 0.3. Next, adjusted family income was partitioned into deciles, using the same cut-points for the entire country. For the Canadian Community Health Survey, income deciles were constructed in the same manner, except that total household income was used rather than total economic family income.

Because of the high proportion of missing income data on the Canadian Community Health Survey (21.5%, compared with 1.4% for the census), the extent of possible bias was addressed by performing two sets of analyses. The first set completely excluded cases with missing income deciles, and the second set was conducted after the missing decile information was filled in using hot deck imputation.[37] In the latter procedure, groups of Canadian Community Health Survey respondents matched on age, sex and educational attainment were created. For the cases with missing income deciles in each of these groups, a decile value was randomly selected from the pool of complete cases (the "donor" cases). Because the hot deck imputation did not appreciably alter the results (data not shown), all of the analyses presented here are based on cases with originally complete income data from the Canadian Community Health Survey.

### Analytical techniques

#### *Health-adjusted life expectancy*

Health-adjusted life expectancy was estimated using a modified version of the Sullivan[38] method. Chiang's[39] method was used to calculate abridged (five-year age group) period life tables, corresponding standard errors, and 95% confidence intervals for each population subgroup of interest (by age, sex and income decile). Before computing the life tables, it was necessary to: (1) transform baseline age to age at the beginning of each year of follow-up; (2) calculate deaths and person-years at risk separately for each year (or partial year) of follow-up; and (3) pool deaths and person-years at risk at the beginning of each year of follow-up.[33]

Health-related quality of life weights were derived from the Health Utilities Index Mark 3 instrument (HUI3),[40,41] administered to all respondents to the 2000/2001 Canadian

Community Health Survey. The health utilities index measures eight basic domains or attributes of health status: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. Each attribute has five or six levels, ranging from normal to severely limited functioning. For example, the levels of ambulation range from 1 ("able to walk around the neighbourhood without difficulty, and without walking equipment") to 6 ("unable to walk at all"). Respondents were asked a standard set of questions on usual functional ability or capacity, which can be mapped to the levels of the eight attributes. A respondent's health status was thus represented by an eight-element vector listing each of the attribute levels, which were then summarized by a weighted scoring function into a single value representing overall health-related quality of life. The global score has a theoretical range of -0.36 (the worst possible health state) to 1.00 (the best possible health state), where 0.00 represents a health state equivalent to death.

Mean global health utilities index scores were computed from the Canadian Community Health Survey for each population subgroup (by age, sex and income decile). Ten-year rather than five-year age groups were used with the Canadian Community Health Survey data to ensure stability of the mean estimates. Therefore, for computing health-adjusted life expectancy at ten-year intervals (for ages 25 through 75), the appropriate life table elements for five-year age groups from the census-mortality linked data were collapsed (for example, combining ages 25 to 29 with ages 30 to 34). Survey sampling weights were applied to correct the point estimates of the health utilities index means for unequal selection probabilities, post-stratification adjustments, and unit non-response. The Rao-Wu bootstrap technique was used to adjust the standard errors and 95% confidence intervals for the effects of stratification and clustering.[42,43]

After the life table values and corresponding mean global health utilities index scores were assembled, health-adjusted life expectancy was computed using the following formula, separately by sex and within each income decile:

$$HALE_x = \frac{\sum_{i=x}^{w}(L_i * H_i)}{l_x}$$

where:

- $HALE$ is health-adjusted life expectancy;
- $x$ is the exact age for which HALE is estimated (25 to 75, by ten-year intervals);
- $i$ is an indicator representing the lower limit ($x$) of the age interval ($x, x + a$);
- $L_i$ is the number of life years lived by the age group ($x, x + a$);
- $l_x$ is the number of survivors at age $x$;
- $H_i$ is the mean global health utilities index score for the age group ($x, x + a$), with $H_i = 1.00$ indicating full health; and
- $w$ is the total number of age groups in the life table.

Thus, the higher the average level of health-related quality of life for a given age group on a scale with an upper limit of 1.00 (full health), the closer health-adjusted life expectancy will be to conventional life expectancy.

The variance of health-adjusted life expectancy was estimated by adapting methods proposed by Mathers[44] (see Health Canada, 2004[28]), which take into account stochastic fluctuations in the observed death rates and the mean global health utilities index scores. All analyses were performed using a combination of SAS Version 9.1 for Windows (SAS

**Table 1**
**Sample sizes for 1991-2001 Canadian census mortality follow-up study and corresponding weighted population estimates for 2000/2001 Canadian Community Health Survey**

| | Census mortality follow-up study counts | | Canadian Community Health Survey estimates | |
|---|---|---|---|---|
| Variable | Number | Percentage | Millions | Percentage |
| **Total** | **2,735,200** | **100.0** | **25.81** | **100.0** |
| **Sex** | | | | |
| Men | 1,358,400 | 49.7 | 12.71 | 49.2 |
| Women | 1,376,800 | 50.3 | 13.1 | 50.8 |
| **Age group** | | | | |
| 25 to 34 | 772,400 | 28.2 | 4.17 | 20.4 |
| 35 to 44 | 718,500 | 26.3 | 5.32 | 26.0 |
| 45 to 54 | 469,600 | 17.2 | 4.45 | 21.8 |
| 55 to 64 | 352,200 | 12.9 | 2.84 | 13.9 |
| 65 to74 | 272,000 | 9.9 | 2.16 | 10.6 |
| 75 or older | 150,400 | 5.5 | 1.5 | 7.3 |
| **Income decile** | | | | |
| Decile 1 (lowest) | 226,600 | 8.3 | 2.02 | 7.8 |
| Decile 2 | 238,700 | 8.7 | 2.02 | 7.8 |
| Decile 3 | 256,500 | 9.4 | 2.02 | 7.8 |
| Decile 4 | 269,600 | 9.9 | 1.93 | 7.5 |
| Decile 5 | 276,500 | 10.1 | 1.94 | 7.5 |
| Decile 6 | 279,000 | 10.2 | 2.2 | 8.5 |
| Decile 7 | 283,300 | 10.4 | 1.79 | 6.9 |
| Decile 8 | 286,400 | 10.5 | 2.24 | 8.7 |
| Decile 9 | 289,300 | 10.6 | 2.03 | 7.9 |
| Decile 10 (highest) | 289,000 | 10.6 | 2.05 | 7.9 |
| Missing | 39,600 | 1.4 | 5.56 | 21.5 |

**Notes:** Census data were rounded to nearest 100. Percentages were calculated before rounding. Canadian Community Health Survey estimates were weighted to reflect target population size. All income data for the census mortality follow-up were available, but economic family size information was lacking for residents of non-institutional collective dwellings, so adjusted income could not be calculated for 39,600 individuals.
**Sources:** 1991-2001 Canadian census mortality follow-up study, 2000/2001 Canadian Community Health Survey (cycle 1.1).

Institute, Cary North Carolina) and Microsoft Excel 2002 for Windows.

### *Health-adjusted life expectancy by educational attainment*

To verify the robustness of the association between health-adjusted life expectancy and socio-economic status, differences were also estimated for varying levels of education. For both the census mortality linked file and the Canadian Community Health Survey, self-reported information on highest level of education was grouped into four categories: less than secondary graduation, secondary graduation (or trades certificate), postsecondary certificate or diploma (short of a university bachelor's degree), and university degree (bachelor's or higher).

## Results

### *Sample characteristics*

For the most part, the distribution by age, sex and income decile was similar in the census mortality follow-up study and the Canadian Community Health Survey (Table 1). However, the Canadian Community Health Survey had considerably more missing data on the income decile (21.5%) than did the census mortality data (1.4%). As well, 1,565 respondents (about 1.5% of those aged 25 or older) to the Canadian Community Health Survey were missing data on the health utilities index, and were excluded from the analyses.

### *Disparities in mortality*

For both men and women, a clear socio-economic gradient emerged for remaining life expectancy at age 25, as well as for the percentage expected to survive to age 75 (Table 2). From the lowest to the highest income deciles, a gradual yet steady increase in remaining life expectancy at age 25 was evident. For men, the difference in life expectancy between the extreme deciles was 7.4 years, and for women, 4.5 years. The proportion expected to survive to age 75 also climbed steadily, with 51% of men in the lowest income decile expected

**Table 2**
**Remaining life expectancy at age 25 and percent expected to survive to age 75, by income decile and sex, Canada, 1991-2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | | 95% confidence interval | | | 95% confidence interval | |
| Income decile in 1991 | Years | from | to | Years | from | to |
| **Remaining life expectancy at age 25** | | | | | | |
| Decile 1 (lowest) | 48.6 | 48.4 | 48.9 | 56.5 | 56.2 | 56.7 |
| Decile 2 | 49.5 | 49.3 | 49.8 | 57.0 | 56.8 | 57.2 |
| Decile 3 | 51.1 | 50.9 | 51.3 | 58.2 | 58.0 | 58.4 |
| Decile 4 | 52.1 | 51.9 | 52.3 | 59.1 | 58.9 | 59.3 |
| Decile 5 | 52.9 | 52.7 | 53.1 | 59.4 | 59.2 | 59.6 |
| Decile 6 | 53.2 | 53.0 | 53.3 | 59.8 | 59.5 | 60.0 |
| Decile 7 | 53.8 | 53.6 | 54.0 | 59.9 | 59.7 | 60.1 |
| Decile 8 | 54.4 | 54.2 | 54.5 | 60.1 | 59.9 | 60.3 |
| Decile 9 | 54.8 | 54.6 | 54.9 | 60.6 | 60.3 | 60.8 |
| Decile 10 (highest) | 56.0 | 55.8 | 56.2 | 61.0 | 60.8 | 61.1 |
| Difference: Decile 10 minus Decile 1 | 7.4 | 7.1 | 7.7 | 4.5 | 4.2 | 4.8 |
| **Percent expected to survive to age 75** | **%** | **from** | **to** | **%** | **from** | **to** |
| Decile 1 (lowest) | 51.2 | 50.4 | 52.1 | 69.4 | 68.7 | 70.1 |
| Decile 2 | 53.6 | 52.7 | 54.5 | 73.1 | 72.4 | 73.8 |
| Decile 3 | 58.7 | 58.0 | 59.5 | 76.6 | 75.9 | 77.2 |
| Decile 4 | 61.7 | 61.0 | 62.4 | 78.9 | 78.3 | 79.5 |
| Decile 5 | 64.2 | 63.5 | 64.9 | 80.1 | 79.5 | 80.7 |
| Decile 6 | 65.4 | 64.7 | 66.1 | 80.8 | 80.2 | 81.4 |
| Decile 7 | 67.3 | 66.6 | 67.9 | 81.7 | 81.1 | 82.3 |
| Decile 8 | 69.1 | 68.4 | 69.7 | 82.0 | 81.4 | 82.6 |
| Decile 9 | 70.9 | 70.3 | 71.5 | 83.4 | 82.8 | 83.9 |
| Decile 10 (highest) | 74.6 | 74.0 | 75.1 | 84.4 | 83.9 | 85.0 |
| Difference: Decile 10 minus Decile 1 | 23.3 | 22.3 | 24.3 | 15.0 | 14.2 | 15.9 |

Source: 1991-2001 Canadian census mortality follow-up study

**Table 3**
**Mean health utilities index scores for Canadian Community Health Survey respondents aged 25 to 34, by income decile and sex, 2000/2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Health utilities index | 95% confidence interval | | Health utilities index | 95% confidence interval | |
| Income decile in 2000/2001 | score | from | to | score | from | to |
| Decile 1 (lowest) | 0.864 | 0.841 | 0.886 | 0.865 | 0.850 | 0.879 |
| Decile 2 | 0.893 | 0.874 | 0.913 | 0.885 | 0.870 | 0.900 |
| Decile 3 | 0.907 | 0.889 | 0.925 | 0.892 | 0.870 | 0.914 |
| Decile 4 | 0.922 | 0.909 | 0.935 | 0.905 | 0.889 | 0.920 |
| Decile 5 | 0.922 | 0.906 | 0.937 | 0.913 | 0.898 | 0.927 |
| Decile 6 | 0.933 | 0.922 | 0.944 | 0.915 | 0.904 | 0.926 |
| Decile 7 | 0.927 | 0.915 | 0.939 | 0.930 | 0.919 | 0.942 |
| Decile 8 | 0.938 | 0.928 | 0.947 | 0.925 | 0.911 | 0.939 |
| Decile 9 | 0.936 | 0.920 | 0.951 | 0.935 | 0.925 | 0.945 |
| Decile 10 (highest) | 0.951 | 0.942 | 0.959 | 0.943 | 0.933 | 0.953 |
| Difference: Decile 10 minus Decile 1 | 0.087 | 0.063 | 0.111 | 0.078 | 0.060 | 0.096 |

Note: Health utilities index scores based on HUI3
Source: 2000/2001 Canadian Community Health Survey (cycle 1.1)

to reach age 75, compared with 75% of those in the highest income decile. The corresponding figures for women were 69% versus 84%, a smaller inter-decile gap.

### *Disparities in health-related quality of life*

Average health-related quality of life scores also exhibited appreciable socio-economic gradients. Table 3 shows mean health utilities index scores by income adequacy decile for people aged 25 to 34. For both sexes, mean scores tended to rise with income.

It is useful to evaluate these disparities in terms of a criterion called the *minimal clinically important difference*, which is the smallest difference that reflects a meaningful impact on (or change in) health-related quality of life.[15] For global scores on the health utilities index—in particular, the Mark 3 version used here—a minimal clinically important difference of 0.03 has been established through a combination of empirical research and expert opinion.[16] In the present study, the difference in mean global health utilities index scores between men in the highest income group (decile 10) and those in the lowest (decile 1) was 0.087, almost three times the minimal clinically important difference. The corresponding difference for women was 0.078.

### *Disparities in health-adjusted life expectancy*

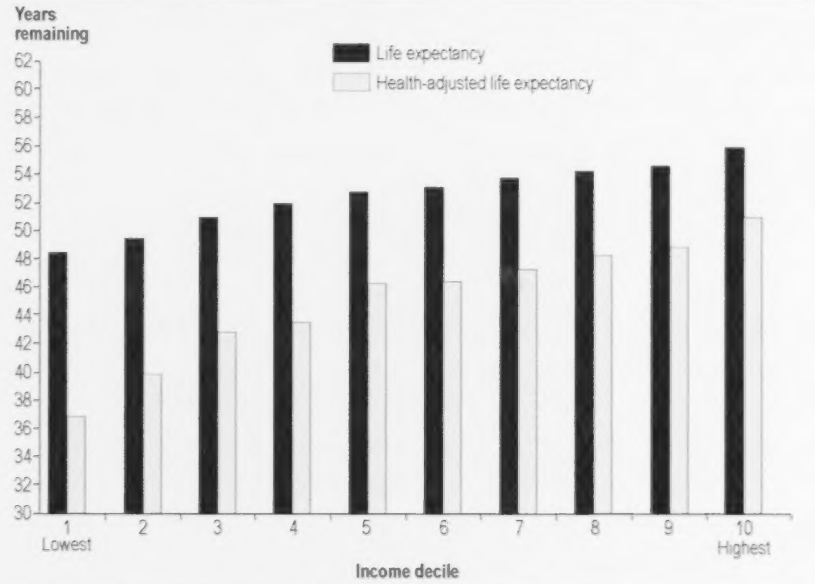
Remaining health-adjusted life expectancy at age 25 is shown in Table 4, and disparities across the income deciles in both conventional life expectancy and health-adjusted life expectancy are displayed in Figures 1 and 2. As with conventional life expectancy, for both sexes, the results for health-adjusted life expectancy demonstrated a nearly linear gradient with respect to income. Disparities in health-adjusted life expectancy between the highest and lowest deciles were 14.1 years for men and 9.5 years for women, whereas the corresponding disparities in conventional life expectancy were only 7.4 and 4.5 years, respectively.

**Table 4**
**Remaining health-adjusted life expectancy (years) at age 25, by income decile and sex, Canada, 1991-2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | | 95% confidence interval | | | 95% confidence interval | |
| Income decile | Years | from | to | Years | from | to |
| Decile 1 (lowest) | 37.0 | 36.4 | 37.5 | 42.9 | 42.4 | 43.3 |
| Decile 2 | 40.0 | 39.5 | 40.4 | 45.6 | 45.2 | 46.0 |
| Decile 3 | 43.0 | 42.6 | 43.3 | 48.4 | 48.0 | 48.8 |
| Decile 4 | 43.7 | 43.3 | 44.1 | 49.3 | 48.8 | 49.8 |
| Decile 5 | 46.4 | 46.0 | 46.7 | 49.7 | 49.2 | 50.2 |
| Decile 6 | 46.5 | 46.1 | 46.9 | 51.2 | 50.7 | 51.7 |
| Decile 7 | 47.4 | 47.1 | 47.7 | 50.7 | 50.2 | 51.3 |
| Decile 8 | 48.4 | 48.0 | 48.8 | 51.8 | 51.1 | 52.6 |
| Decile 9 | 49.0 | 48.6 | 49.3 | 52.2 | 51.7 | 52.8 |
| Decile 10 (highest) | 51.1 | 50.8 | 51.4 | 52.4 | 51.4 | 53.4 |
| Difference: Decile 10 minus Decile 1 | 14.1 | 13.5 | 14.8 | 9.5 | 8.5 | 10.6 |

Source: 1991-2001 Canadian census mortality follow-up study, 2000/2001 Canadian Community Health Survey (cycle 1.1)

**Figure 1**
**Remaining life expectancy and health-adjusted life expectancy at age 25, by income decile, men, Canada, 1991-2001**

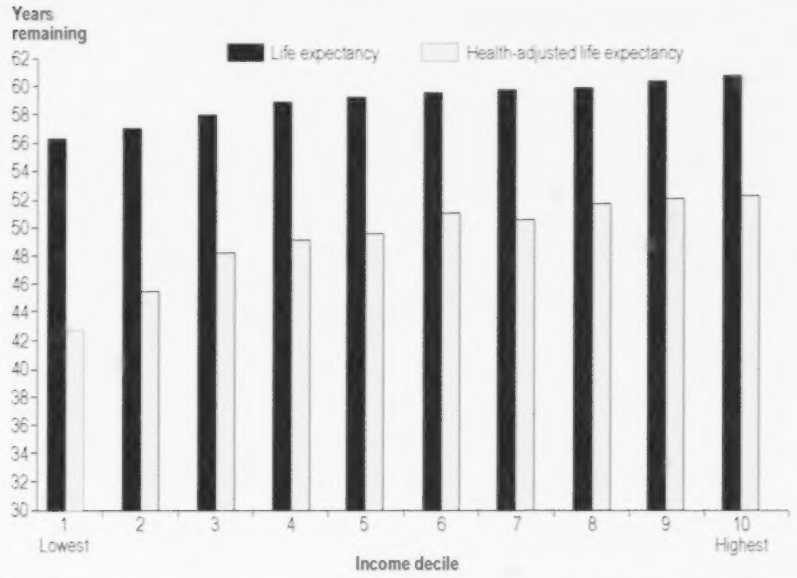



Source: 1991-2001 Canadian census mortality follow-up study, 2000/2001 Canadian Community Health Survey (cycle 1.1)

### *Health disparities across education levels*

The results of the supplemental analyses of health disparities across educational attainment categories are shown in Appendix Tables A, B and C. Without exception, all of the health indicators (life expectancy, survival probabilities, mean health utilities index scores, and health-adjusted life expectancy) showed

**Figure 2**
**Remaining life expectancy and health-adjusted life expectancy at age 25, by income decile, women, Canada, 1991-2001**




Source: 1991-2001 Canadian census mortality follow-up study, 2000/2001 Canadian Community Health Survey (cycle 1.1)

steady improvement with increasing levels of education.

## Discussion

This study indicates strong and consistent evidence of socio-economic disparities in health. Income-related disparities in health-adjusted life expectancy were found to be considerably larger than those for the conventional life expectancy indicator. For both men and women at age 25, the difference in remaining health-adjusted life expectancy between the highest and lowest income groups was much larger than the corresponding difference in overall life expectancy: 6.8 years more for men, and 5.0 years more for women. These results highlight the generally worse morbidity that lower-income groups experience in addition to their higher mortality. The findings are consistent with those of other Canadian investigations using area-level[28-30] and individual-level[31] indicators of health and socio-economic status, and with numerous studies of socio-economic differences in health expectancy in the United States and Europe.[13-15] This information suggests that the remediation of both fatal and non-fatal health outcomes may have the potential to substantially reduce health disparities related to socio-economic circumstances in Canada.

Some additional perspective on the magnitude of socio-economic disparities in health-adjusted life expectancy can be provided through comparisons with the impact of specific health conditions. For example, Manuel and colleagues[23] found that all cancers, which represented the greatest burden of disease in the population, reduced health-adjusted life expectancy *at birth* by 2.8 years for men and by 2.5 years for women. By contrast, in this analysis, which examines health-adjusted life expectancy at age 25, the difference between the highest income decile and the overall average was estimated at 5.8 years for men and 3.1 years for women. For men, this was around twice the impact of all cancers combined, while for women, it was about the same as the impact for all cancers combined. Because of differences in methodology and data sources, these findings and those of Manuel and colleagues[23] are not completely comparable. But methodological differences alone are unlikely to account for such large discrepancies between the impact of a major disease which has been the object of tremendous research and clinical effort (such as the "war on cancer" in the United States, declared in 1971),[47] and the impact of socio-economic factors, which remain, by comparison, relatively poorly understood. Further research examining pathways by which socio-economic status affects health is warranted to understand how such large differences are generated and to point to potential areas for intervention.

### Limitations

The results of this study pertain to the *non-institutionalized* population aged 25 or older (except that the mortality data included people who were institutionalized after the 1991 Census). Future work should investigate ways of including the morbidity and mortality experience of institutional residents—the most disabled segment of the population—as well as that of people younger than 25, to get a more comprehensive picture of morbidity and mortality in relation to socio-economic status.

The Canadian Community Health Survey data may be affected by a certain element of self-selection, since not everyone contacted agreed to participate in the survey. The health utilities index data from the survey may be subject to self-report error, and may not perfectly reflect the health-related quality of life of the 1991-2001 Canadian census mortality cohort. However, a more representative and temporally consistent source of data on health-related quality of life was not available.

Data on income were missing for a large share of the Canadian Community Health Survey sample. However, imputing the missing income deciles and then recalculating the estimates with complete decile information for the survey component did not substantially change the results (data not shown).

## *What is already known on this subject?*

- Findings from Canada and other countries have consistently demonstrated that accounting for morbidity as well as mortality reveals even greater socio-economic disparities in health outcomes, because of the generally worse morbidity experience of disadvantaged persons.

## *What does this study add?*

- This is the first study to provide nationally representative estimates of socio-economic inequalities in health-adjusted life expectancy for the adult household population of Canada, using individual-level measures of socio-economic status, mortality and morbidity.
- For both sexes, disparities in health-adjusted life expectancy between the highest and lowest income groups were substantially greater than those for life expectancy alone.

The person-equivalence scale used to compute adjusted household income was only one of many possible approaches. For example, other Canadian studies have used the ratio of total income to the Statistics Canada low income cut-off established for the applicable family and community size group.[33] In addition, a variety of alternative indicators of socio-economic status (such as education or occupational prestige) could be used to examine gradients in health. Nonetheless, it is well known that the socio-economic gradient in health is robust to the choice of measurement method. Recomputation of the same set of estimates (for life expectancy, survival probabilities, mean health utilities index score, and health-adjusted life expectancy) for another indicator of socio-economic status (educational attainment) yielded essentially the same pattern of results (Appendix Tables A, B and C).

While the measurement properties of the health utilities index have been supported in numerous studies,[40,46,48] other reliable and valid measures of health-related quality of life can be used in the computation of health-adjusted life expectancy, such as the EuroQol Five Dimensions Index[49] and the Short-Form Six Dimensions Index.[50] However, the health utilities index was the only such measure available from the Canadian Community Health Survey, which, in turn, was the only nationally representative source of health-related quality of life data with a sample of sufficient size. Future studies in the Canadian context could use other instruments if they are included on national surveys. Alternatively, weights could be assigned to particular levels of disability based on expert opinion.[29,30,51] Comparison of the current results and those obtained with such alternative methods would show the sensitivity of health-adjusted life expectancy and of the corresponding socio-economic gradient to changes in the way health-related quality of life is measured.

The 1991-2001 Canadian census mortality follow-up study dataset contained only baseline (1991) information on family income, and the Canadian Community Health Survey provided only cross-sectional estimates of morbidity. Since these characteristics are expected to change over time, it would have been preferable to have income and morbidity information for each year of follow-up, thus providing the input for a more dynamic, multistate life table or microsimulation-based approach to computing health-adjusted life expectancy.[52]

Mathers' method[41] for calculating the variance of health-adjusted life expectancy assumes that the rates of mortality and morbidity are uncorrelated, but violations of this assumption could result in underestimation of the variance using his method.[53] Because individual risk functions for the two variables were not known, it was not possible to estimate the correlation between morbidity and mortality from the present data. Nevertheless, the bias introduced in the variance estimate may have been reduced because all the calculations were done by age, sex and income decile, which themselves explain a substantial amount of the variance in health-related quality of life and mortality.

Although life expectancy, survival probabilities, the health utilities index, and health-adjusted life expectancy were each found to be associated with income in the current study, causality cannot be inferred. In a study of the effects of poverty and material hardship on mortality in Finland, Martikainen and colleagues[54] concluded that a large part of the association observed between income and mortality was not due to a direct causal impact, but rather to the mutual dependence of mortality and income on other background factors such as educational attainment and occupational prestige. Identifying the true causal mechanisms underlying the socio-economic gradient in health is important, since the effectiveness of interventions may rest on correctly understanding the forces involved. The real drivers of health inequalities could be differences in education and occupation. It has also been suggested that poorer health status may be an antecedent to both lower incomes and earlier mortality ("reverse causality").[55] Although health status affects socio-economic status to some degree (for example, chronic illness can result in foregone income and reduced opportunities), several prospective studies have demonstrated that forward causality (socio-economic status influencing health) is more important in generating the observed socio-economic gradient in health.[56-59] Nevertheless, the current descriptive analysis makes no claims about the causal mechanisms underlying the observed health disparities.

## Conclusion

The 1991-2001 census mortality follow-up study has opened a wide range of opportunities for analyzing socio-economic correlates of health in

Canada. The health disparities estimates presented here are novel in that they use Canadian microdata on socio-economic status, mortality and morbidity for a large, representative sample of the household population aged 25 or older. The results provide comprehensive, robust, and policy-relevant information on the distribution of health outcomes by socio-economic status. This study may be useful to identify areas in which interventions for reducing health disparities would yield the greatest benefits. ■

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# References

1. Riley JC. *Rising Life Expectancy: A Global History*. Cambridge, Massachusetts: Cambridge University Press, 2001.
2. Mackenbach JP. *Health Inequalities: Europe in Profile*. London: COI for the Department of Health, 2006. Available at: http://www.who.int/social_determinants/resources/european_inequalities.pdf. Accessed March 26, 2009.
3. Mackenbach JP, Meerding WJ, Kunst AE. *Economic Implications of Socio-economic Inequalities in Health in the European Union*. Luxembourg: European Commission, 2007.
4. Health Disparities Task Group. *Reducing Health Disparities – Role of the Health Sector*. Discussion paper. Ottawa: Public Health Agency of Canada, 2004. Available at: http://www.phac-aspc.gc.ca/ph-sp/disparities/pdf06/disparities_discussion_paper_e.pdf. Accessed October 20, 2008.
5. Raphael D. Health inequalities in Canada: current discourses and implications for public action. *Critical Public Health* 2000;10(2): 193-216.
6. World Health Organization. *Closing the Gap in a Generation: Health Equity Through Action on the Social Determinants of Health*. Final Report of the Commission on Social Determinants of Health. Geneva: World Health Organization, 2008.
7. Wilkins R, Berthelot JM, Ng E. Trends in mortality by neighbourhood income in urban Canada from 1971 to 1996. *Health Reports* (Statistics Canada, Catalogue 82-003) 2002; 13 (Supplement): 45-71.
8. James PD, Wilkins R, Detsky AS, et al. Avoidable mortality by neighbourhood income in Canada: 25 years after the establishment of universal health insurance. *Journal of Epidemiology and Community Health* 2007; 61: 287-96.
9. Eng K, Feeny D. Comparing the health of low income and less well educated groups in the United States and Canada. *Population Health Metrics* 2007; 5: 10.
10. Kopec JA, Williams JI, To T, Austin PC. Measuring population health: correlates of the Health Utilities Index among English and French Canadians. *Canadian Journal of Public Health* 2000; 91(6): 465-70.
11. Marra CA, Lynd LD, Esdaile JM, et al. The impact of low family income on self-reported health outcomes in patients with rheumatoid arthritis within a publicly funded health-care environment. *Rheumatology* 2004; 43: 1390-7
12. Roberge R, Berthelot JM, Wolfson M. The Health Utility Index: Measuring health differences in Ontario by socioeconomic status. *Health Reports* (Statistics Canada, Catalogue 82-003) 1995; 7: 25-32.
13. Bossuyt N, Gadeyne S, Deboosere P, Van Oyen H. Socio-economic inequalities in health expectancy in Belgium. *Public Health* 2004; 118(1): 3-10.
14. Crimmins EM, Cambois E. Social inequalities in health expectancy. In: Robine JM, Jagger C, Mathers CD, et al., eds. *Determining Health Expectancies*. Chichester, England: Wiley, 2003: 111-25.
15. Wood R, Sutton M, Clark D, et al. Measuring inequalities in health: the case for healthy life expectancy. *Journal of Epidemiology and Community Health* 2006; 60:1089-92.
16. Murray CJL, Lopez AD, eds. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020*. Volume 1. Boston: Harvard University Press; 1996.
17. Robine JM, Jagger C, Mathers CD, Crimmins EM, Suzman RM, eds. *Determining Health Expectancies*. Chichester, England: Wiley, 2003.
18. Murray CJL, Salomon JA, Mathers CD, Lopez AD, eds. *Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications*. Geneva: World Health Organization, 2002.
19. Wolfson MC. Health-adjusted life expectancy. *Health Reports* (Statistics Canada, Catalogue 82-003) 1996; 8(1): 41-6.
20. Mayer F, Ross N, Berthelot JM, Wilkins R. Disability-free life expectancy by health region. *Health Reports* (Statistics Canada, Catalogue 82-003) 2002; 13(4): 49-60.
21. Boswell-Purdy J, Flanagan WM, Roberge H, et al. Population health impact of cancer in Canada, 2001. *Chronic Diseases in Canada* 2007; 28(1-2): 42-55.
22. Manuel DG, Schultz SE. Using linked data to calculate summary measures of population health: health-adjusted life expectancy of people with diabetes mellitus. *Population Health Metrics* 2004; 2: 4.
23. Manuel DG, Luo W, Ugnat A-M, Mao Y. Cause-deleted health-adjusted life expectancy of Canadians with selected chronic conditions. *Chronic Diseases in Canada* 2003; 24(4): 108-15.
24. Manuel DG, Schultz SE, Kopec JA. Measuring the health burden of chronic disease and injury using health-adjusted life expectancy and the Health Utilities Index. *Journal of Epidemiology and Community Health* 2002; 56: 843-50.
25. Bélanger A, Martel L, Berthelot JM, Wilkins R. Gender differences in disability-free life expectancy for selected risk factors and chronic conditions in Canada. *Journal of Women and Aging* 2002; 14: 61-83.
26. Martel L, Bélanger A. An analysis of the change in dependence-free life expectancy in Canada between 1986 and 1996. In: Bélanger A, Gilbert S, eds. *Report on the Demographic Situation in Canada 1998-1999* (Statistics Canada, Catalogue 91-209-XPE) Ottawa: Minister of Industry, 1999: 164-86 (and Erratum).
27. Roberge R, Berthelot JM, Cranswick K. Adjusting life expectancy to account for disability in a population: A comparison of three techniques. *Social Indicators Research* 1999; 48(2): 217-43.

28. Health Canada. *Healthy Canadians: A Federal Report on Comparable Health Indicators 2004*. Ottawa: Health Canada, 2004.

29. Wilkins R, Adams O. *Healthfulness of Life: A Unified View of Mortality, Institutionalization and Non-Institutionalized Disability in Canada, 1978*. Montreal: Institute for Research on Public Policy, 1983.

30. Wilkins R, Adams OB. Health expectancy in Canada, late 1970s: demographic, regional, and social dimensions. *American Journal of Public Health* 1983; 73: 1073-80.

31. Nault F, Roberge R, Berthelot JM. Espérance de vie et espérance en santé selon le sexe, l'état matrimonial et le statut socio-économique au Canada. *Cahiers Québécois de Démographie* 1996; 25(2): 241-59.

32. Berthelot JM. Health-adjusted life expectancy. In: Robine JM, Jagger C, Mathers CD, et al., eds. *Determining Health Expectancies*. Chichester, England: Wiley, 2003: 235-46.

33. Wilkins R, Tjepkema M, Mustard CA, Choinière R. The Canadian census-mortality follow-up study, 1991 to 2001. *Health Reports* (Statistics Canada, Catalogue 82-003) 2008; 19(3): 25-43. Available at: http://www.statcan.ca/english/freepub/82-003-XIE/2008003/article/10681-en.pdf .

34. Béland Y. Canadian community health survey: Methodological overview. *Health Reports* (Statistics Canada, Catalogue 82-003) 2002; 13(3): 9-14.

35. Statistics Canada. *Canadian Community Health Survey (CCHS): Questionnaire for Cycle 1.1*. Ottawa: Statistics Canada, 2002. Available at: http://www.statcan.gc.ca/imdb-bmdi/instrument/3226_Q1_V1-eng.pdf

36. Statistics Canada. *1991 Census Dictionary* (Catalogue 92-301E, POPLINE Document Number: 241233) Ottawa: Statistics Canada, 1992.

37. Ford BL. An overview of hot-deck procedures. In: Madow WG, Olkin I, Rubin DB, eds. *Incomplete Data in Sample Surveys*. New York: Academic Press, 1983: 185-207.

38. Sullivan DF. A single index of mortality and morbidity. *HSMHA Health Reports* 1971; 86: 347-54.

39. Chiang CL. *The Life Table and its Applications*. Malabar, Florida: Robert E. Krieger, 1984.

40. Feeny D. The Health Utilities Index: A tool for assessing health benefits. *Patient Reported Outcomes Newsletter* 2005; 34: 2-6.

41. Feeny D, Furlong W, Torrance GW, et al. Multi-attribute and single-attribute utilities functions for the Health Utilities Index Mark 3 system. *Medical Care* 2002; 40(2): 113-28.

42. Rao JNK, Wu CFJ. Resampling inference with complex survey data. *Journal of the American Statistical Association* 1988; 83: 231-41.

43. Rao JNK, Wu CFJ, Yue K. Some recent work on resampling methods. *Survey Methodology* (Statistics Canada, Catalogue 12-001) 1992; 18: 209-17.

44. Mathers C. *Health Expectancies in Australia 1981 and 1988*. Canberra: Australian Institute of Health and Welfare, AGPS, 1991.

45. Guyatt GH, Osoba D, Wu AW, et al. Methods to explain the clinical significance of health status measures. *Mayo Clinic Proceedings* 2002; 77: 371-83.

46. Horsman J, Furlong W, Feeny D, Torrance G. The Health Utilities Index (HUI®): Concepts, measurement properties and applications. *Health and Quality of Life Outcomes* 2003; 1: 54.

47. Howe GK, Clapp RW. Are we winning or losing the war on cancer? Deciphering the propaganda of NCI's 33-year war. *New Solutions: A Journal of Environmental and Occupational Health Policy* 2004; 14(2): 109-24.

48. Furlong WJ, Feeny DH, Torrance GW, Barr RD. The Health Utilities Index (HUI) system for assessing health-related quality of life in clinical studies. *Annals of Medicine* 2001; 33: 375-84.

49. Shaw JW, Johnson JA, Coons SJ. US valuation of the *EQ-5D* health states: development and testing of the D1 model. *Medical Care* 2005; 43: 203-20.

50. Brazier J, Usherwood T, Harper R, Thomas K. Deriving a preference-based single index from the UK SF-36 Health Survey. *Journal of Clinical Epidemiology* 1998; 51(11): 1115-28.

51. Murray CJL. Rethinking DALYs. In: Murray CJL, Lopez AD, eds. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020*. Volume 1. Boston, Massachusetts: Harvard University Press; 1996: 1-98.

52. Wolfson MC. POHEM – A framework for understanding and modeling the health of populations. *World Health Statistics Quarterly* 1994; 47: 157-76.

53. Barendregt JJ. Confidence intervals for health expectancy. *International Network on Health Expectancy (REVES)*. Hammamet, Tunisa: April 24-26, 2002.

54. Martikainen P, Mäkelä P, Koskinen S, Valkonen T. Income differences in mortality: A registry-based follow-up of three million men and women. *International Journal of Epidemiology* 2001; 30: 1397-405.

55. West P. Rethinking the health selection explanation for health inequalities. *Social Science and Medicine* 1991; 32: 337-84.

56. Wolfson MC, Rowe G, Gentleman JF, Tomiak M. Career earnings and death: a longitudinal analysis of older Canadian men. *Journal of Gerontology: Social Sciences* 1993; 49(4): 5167-79.

57. Benzeval M, Judge K. Income and health: The time dimension. *Social Science and Medicine* 2001; 52(9): 1371-90.

58. Muennig P. Health selection vs. causation in the income gradient: What can we learn from the graphical trends? *Journal of Health Care for the Poor and Underserved* 2008; 19(2): 574-9.

59. Turrell G, Lynch JW, Leite C, et al. Socioeconomic disadvantage in childhood and across the life course and all-cause mortality and physical function in adulthood: evidence from the Alameda County study. *Journal of Epidemiology and Community Health* 2007; 61: 723-30.

## Appendix

### Table A
**Remaining life expectancy at age 25 and percent expected to survive to age 75, by highest level of educational attainment and sex, Canada, 1991-2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | | 95% confidence interval | | | 95% confidence interval | |
| Educational attainment in 1991 | Years | from | to | Years | from | to |
| **Remaining life expectancy at age 25** | | | | | | |
| Less than secondary graduation (lowest) | 50.8 | 50.7 | 50.9 | 57.8 | 57.7 | 57.8 |
| Secondary graduation | 53.2 | 53.1 | 53.2 | 59.6 | 59.4 | 59.7 |
| Postsecondary diploma | 55.1 | 54.8 | 55.3 | 60.7 | 60.5 | 60.8 |
| University degree (highest) | 56.4 | 56.2 | 56.6 | 61.5 | 61.3 | 61.8 |
| Difference: highest minus lowest | 5.6 | 5.4 | 5.8 | 3.8 | 3.5 | 4.0 |
| **Percent expected to survive to age 75** | % | from | to | % | from | to |
| Less than secondary graduation (lowest) | 58.6 | 58.3 | 5.09 | 75.8 | 75.5 | 76.1 |
| Secondary graduation | 65.6 | 65.3 | 66.0 | 80.5 | 80.2 | 80.9 |
| Postsecondary diploma | 71.0 | 70.2 | 71.7 | 83.0 | 82.5 | 83.4 |
| University degree (highest) | 76.1 | 75.5 | 76.7 | 85.4 | 84.7 | 86.0 |
| Difference: highest minus lowest | 17.4 | 16.8 | 18.1 | 9.6 | 8.9 | 10.3 |

Source: 1991-2001 Canadian census mortality follow-up study

### Table B
**Mean health utilities index scores for Canadian Community Health Survey respondents aged 25 to 34, by highest level of educational attainment and sex, 2000/2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Health utilities index | 95% confidence interval | | Health utilities index | 95% confidence interval | |
| Educational attainment | score | from | to | score | from | to |
| Less than secondary graduation (lowest) | 0.868 | 0.848 | 0.888 | 0.835 | 0.814 | 0.857 |
| Secondary graduation | 0.912 | 0.905 | 0.920 | 0.895 | 0.888 | 0.902 |
| Postsecondary diploma | 0.934 | 0.925 | 0.943 | 0.916 | 0.909 | 0.923 |
| University degree (highest) | 0.946 | 0.938 | 0.953 | 0.942 | 0.936 | 0.947 |
| Difference: highest minus lowest | 0.078 | 0.057 | 0.099 | 0.107 | 0.084 | 0.129 |

Note: Health utilities index scores based on HUI3.
Source: 2000/2001 Canadian Community Health Survey (cycle 1.1)

### Table C
**Remaining health-adjusted life expectancy at age 25, by highest level of educational attainment and sex, Canada, 1991-2001**

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | | 95% confidence interval | | | 95% confidence interval | |
| Educational attainment | Years | from | to | Years | from | to |
| Less than secondary graduation (lowest) | 41.6 | 41.3 | 41.8 | 45.7 | 45.4 | 46.0 |
| Secondary graduation | 45.6 | 45.4 | 45.8 | 49.9 | 49.7 | 50.2 |
| Postsecondary diploma | 48.7 | 48.4 | 49.0 | 51.8 | 51.5 | 52.1 |
| University degree (highest) | 50.7 | 50.4 | 51.0 | 53.1 | 52.6 | 53.6 |
| Difference: highest minus lowest | 9.1 | 8.7 | 9.5 | 7.4 | 6.9 | 8.0 |

Source: 1991-2001 Canadian census mortality follow-up study; 2000/2001 Canadian Community Health Survey (cycle 1.1).

## *Notice of corrections*

**Corrections were made to this product in August, 2010**

Please note the following changes:

**Data errors were found in:**
Table 4 (Remaining health-adjusted life expectancy (years) at age 25, by income decile and sex, Canada, 1991-2001); Figure 1 (Remaining life expectancy and health-adjusted life expectancy at age 25, by income decile, men, Canada, 1991-2001); Figure 2 (Remaining life expectancy and health-adjusted life expectancy at age 25, by income decile, women, Canada, 1991-2001); and Appendix Table C (Remaining health-adjusted life expectancy (years) at age 25, by educational attainment and sex, Canada, 1991-2001).

The data in these tables and charts for both the HTML and PDF versions were corrected and replaced.

**The text was revised to reflect these corrections:**

***Results***
***Disparities in health-adjusted life expectancy***

*Third sentence (page 59):*
Disparities in health-adjusted life expectancy between the highest and lowest deciles were 14.1 years for men and 9.5 years for women, whereas the corresponding disparities in conventional life expectancy were only 7.4 and 4.5 years, respectively.

***Discussion***

*First paragraph, third sentence (page 60):*
For both men and women at age 25, the difference in remaining health-adjusted life expectancy between the highest and lowest income groups was much larger than the corresponding difference in overall life expectancy: 6.8 years more for men, and 5.0 years more for women.

*Second paragraph, third sentence (page 60):*
By contrast, in this analysis, which examines health-adjusted life expectancy at age 25, the difference between the highest income decile and the overall average was estimated at 5.8 years for men and 3.1 years for women. For men, this was around twice the impact of all cancers combined, while for women, it was about the same as the impact for all cancers combined.